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THE TRANSMISSION OF HYDROGEN THROUGH PALLADIUM

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Nearly one-hundred years ago (1869), Thomas Graham discovered that hydrogen gas was soluble in palladium metal. At that time this was the only known case of solubility of a gas in a solid metal at ordinary temperatures. Today many examples of dissolution of gases such as H_2 , O_2 , N_2 in metals are known. The phenomenon is particularly common at high temperatures. Palladium is unique in the respect that it can dissolve relatively large amounts of hydrogen (seven atoms of hydrogen for every ten atoms of palladium) and still maintain a coherent structure which is only slightly different from that of the pure palladium. Other metals which dissolve comparably large amounts of hydrogen disintegrate into powder.

After Graham's discovery, the system, palladium-hydrogen, was studied extensively by many investigators. They established that the hydrogen in the metal is present as atoms not as diatomic molecules. These atoms can move rather freely through the metal. Now suppose that a compartment containing hydrogen gas, H_2 , is separated by a palladium foil from a compartment which is evacuated. A hydrogen molecule in the first compartment can sit down on the surface of the palladium, dissociate into H atoms on the surface, then the H atom can jump into the metal, diffuse through the metal to the other side, jump out onto the surface, then combine with another H atom to form an H_2 molecule which can fly off the surface into the evacuated compartment. Each of these steps in this series of processes requires more or less time to occur. By studying the rate at which hydrogen appears in the compartment which was initially

evacuated, information can be obtained about the rate at which the individual steps, called elementary steps, occur.

We have found, for example, that the rate at which H atoms combine to form H_2 on the surface is much too fast to measure by the technique we employed. The two slow steps in the series of processes are the diffusion of the atom through the metal and the jump of the metal atom from the surface into the bulk of the metal. This jump step is, however, about ten times faster than the diffusion step through a foil of 0.01 inch thickness. On a foil of 0.001 inch thickness the rate of diffusion and the rate of the jump step are roughly comparable.

Aside from the basic interest and gain of knowledge about the way in which elementary actions between atoms and molecules occur, this problem has interest also from the practical standpoint. If one were to use hydrogen in a fuel cell to produce electrical energy, the hydrogen must be supplied to the anode of the electrical cell where it is oxidized. If the anode were of palladium, the hydrogen could diffuse from the fuel supply through the electrode to the interior of the cell where it would be oxidized and produce electrical power. This study would indicate that the maximum current which could be gotten from a cell of this design would be about 0.2 to 0.3 ampere per square centimeter of electrode area. Special types of electrodes have been designed which can consume hydrogen and produce larger currents from each square centimeter of electrode surface.